Performance Limits of Stereoscopic Viewing Systems Using Active and Passive Glasses

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Abstract - The contribution to the "ghost " image from phosphor persistence in time sequential stereoscopic displays is discussed. The use of a segmented shutter, or a rare-earth phosphor is shown to result in a reduced ghost image intensity.

Introduction

One of the most feasible approaches for producing a "3D" viewing system is to sequentially display the left and right eye views of an object on a CRT, and to have an apparatus to ensure that the CRT's image is blocked from reaching the right eye when the left eye's image is being displayed and from reaching the left eye when the right image is being displayed.

A measure of the performance of the 3D viewing system is the leakage of the left eye's view that improperly gets to the right eye (and the leakage of the right eye's view that gets to the left eye). Users viewing images on systems with significant leakage will see a "ghost image" that is bothersome and makes fusion of the stereo pair more difficult.

To minimize this leakage and therefore the ghost image intensity, it is first of all necessary to have an electro-optical device that can switch rapidly, effectively block light in one of its states, and have a wide angle of view.

Nematic liquid crystals are will known electro-optical devices that have many good characteristics, but shutter devices built using them typically ether have a rather slow response speed (around 10 ms) or have a poor angle of view.

A device that was designed in an attempt to get faster switching speeds while maintaining an acceptable angle of view has been developed by Tektronix [1]. The device, called the π-cell, obtains it's speed improvement over usual LC devices of moderate thickness (around 5 microns) by controlling flow induced torques on the director field. This is done by having the surfaces of the cell are treated so that the director at the two surfaces are not parallel, but rather are tilted in opposite directions. In this type of device the material flow does not slow the relaxation of the device and as a consequence a relatively fast switching shutter with a high extinction ratio has been developed.

This type of device is then possibly a good candidate for use in stereoscopic viewing systems to block light from getting to the incorrect eye. But there are other problems in achieving a low ghost image intensity.

0-7803-1363-1/93 $3.00

The Phosphor Persistence Problem in Stereoscopic Viewing Systems Using Active Glasses

Figure 1 shows System Leakage Ratio data for an example active glasses stereoscopic viewing system using the shutter described above. This data was acquired for a system where the video scan for each field required 8 msec, and where successive fields were separated by a 1 ms blanking interval. Because the physical size of the display screen is not relevant to the considered performance characteristics, it is convenient to express the location of a measurement point as the time from the beginning of video, rather than the as the distance from the top of the screen.

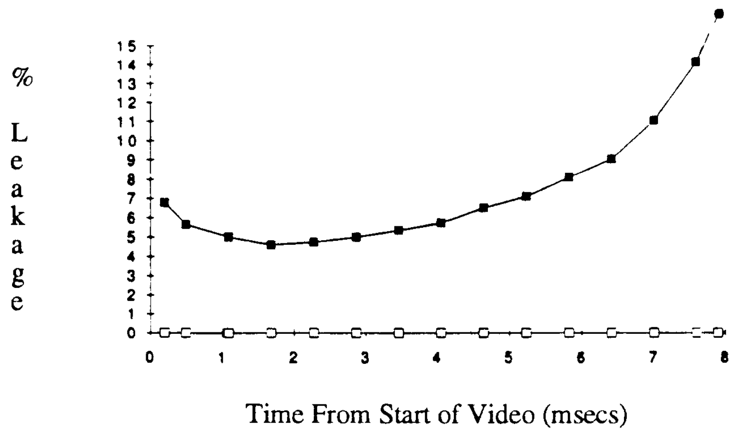

Figure 1: The SLR for Active Glasses with a P-22 phosphor

In considering the performance of the example system , the non-uniformity of the SLR from the top to the bottom of the screen it noticeable. To better understand the causes for these variations it is helpful to acquire data taken from the cell alone presented in similar manner to figure 1.

That data shows the Cell Leakage Ratio is <1% for the entire scan of the incorrect image. Therefore the non-zero values of the curve in figure 1 mostly results from the persistence of the light emission from the phosphor for a significant amount of time after it has been scanned. The following numbers give the amount of light that is emitted in successive milliseconds after a color CRT with the P-22 phosphor is scanned (normalized so that the sum of the luminances is 100): 76; 8; 4; 3; 2; 2; 1; 1; 0; 0; 0; 0; 1; 1; 1; 0; 0; 0. Specifically the data was acquired by measuring the area under the luminance vs time curve, for successive milliseconds, taken for a spot on a CRT that was being refreshed at a 55 Hz rate. It can be seen that about 16% of the total light flux emitted from a point on the screen is emitted in the time interval beginning 2 milliseconds after the point is scanned. This explains the lowering of the SLR at the bottom of the screen, because even though the shutter has a very low transmission when points of the "incorrect" image near the bottom of the screen are scanned, the shutter is switched to a high transmission state one or two milliseconds later and a significant percentage of the light emitted from those points is collected by the "incorrect" eye.

The Improvement Resulting From the Use of a Stereoscopic Viewing System Using Passive Glasses

Stereoscopic viewing systems using passive glasses have been proposed by Mash et.el [2]. The system used a common twisted nematic device on the front of the CRT. With this arrangement, the TN device controls the polarization of light leaving the CRT so that, for example, light leaving the cell during the time interval that the left eye's image is being scanned on the CRT is horizontally linearly polarized, and light leaving the cell during when the right eye's image is being scanned is vertically polarized. The viewer than wears polarized glasses that transmit only horizontally polarized light to the left eye, and only vertically polarized light to the right eye.

A problem with this system is the switching speed of TN devices. For systems where each eye's image is refreshed at a 60 Hz. rate, the time for one video scan will be about 8 msec.; so we will need a device that can switch in a small fraction of this time. Unfortunately, "fast" TN devices require about 10 msec to switch to their relaxed state.

Many electro-optical effects have also been considered for a system using passive glasses, but because of it's acceptable switching speed and angle of view, the π-cell is currently the most commonly used and will be used as an example device to consider system design issues.

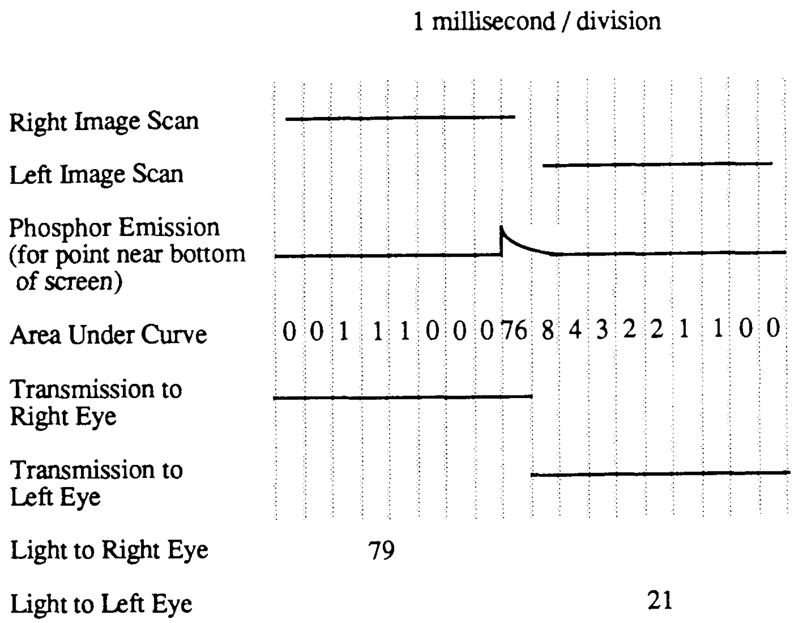

Figure 2: Contribution to the SLR of Phosphor Persistence for a System Using an Unsectioned Shutter (or active glasses) and a P-22 Color Phosphor Set

A basic design consideration that can be addressed with a passive glasses system has to do with phosphor decay. In the case of active glasses there is not much that can be done about this problem, but in the case of a passive glasses system it is possible to electrically section the LC cell at the CRT into sections that can be switched independently to allow more time for phosphor decay. For the purposes of illustration of this point consider the case of a shutter that switches instantaneously and that has perfect extinction. Figure-2 shows for an un-sectioned shutter (or active glasses) that at a point near the bottom of the screen the System Leakage Ratio (as defined earlier) is limited to 26.5% for a phosphor with the decay characteristics listed previously. The reason for this high leakage, as discussed in the section on active glasses, is caused because the shutter switches to allow light to pass to the left eye while the right eye's image is still glowing (and vs.vs.). In the figure 21% of the light from the right eye's image is actually transmitted to the left eye.

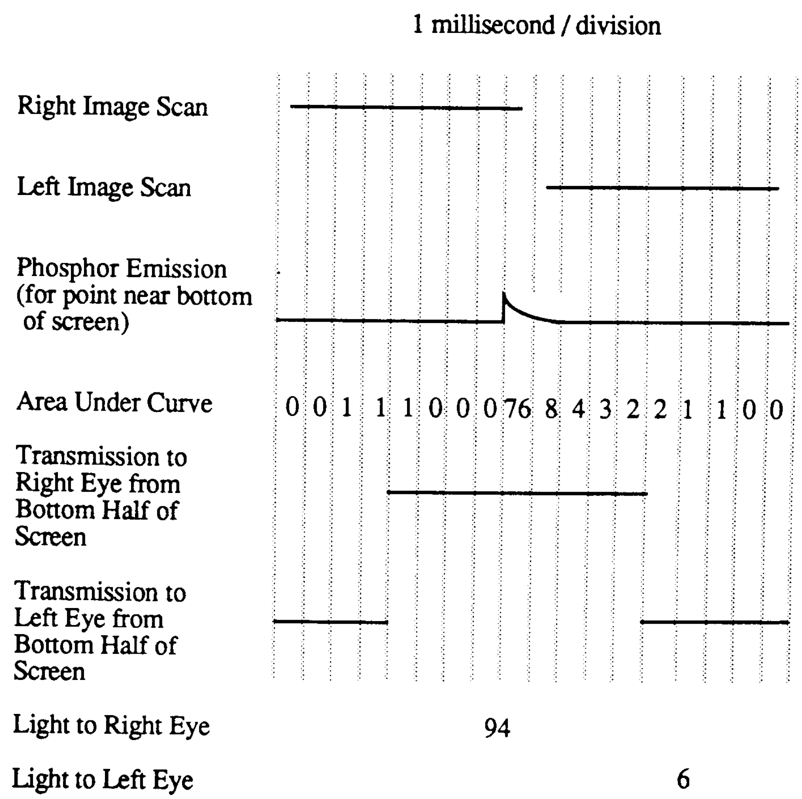

Figure 3: Contribution to the SLR of Phosphor Persistence for a System Using a Two Section Shutter and a P-22 Color Phosphor Set

Figure 3 is similar to Figure 2 except the shutter has been electrically divided into top and bottom sections is considered. In this case, as shown, the bottom section of the shutter can continue to send the light from the lower half of the CRT to the right eye even while the top half of the left eye's image is being scanned on the CRT. Having the lower section able to

send light to the right eye for an additional 4 msec. decreases the light from the right eye's image that is sent to the left eye to 5.8% of the amount of light sent to the right eye.

Dividing the cell into more sections further decreases the leakage of the "incorrect" image due to phosphor persistence. If a five section cell is used the amount of light sent to the left eye is decreased to 3.6% if the timing of figure 2 is used.

The fact that real shutters have a distinctly non-instantaneous switch to the half-wave state modifies the light leakage due to phosphor decay. This results because the available time from when the image behind a section finishes being scanned at the section bottom, until it is beginning to be scanned at it's top is partially used by the time required for the shutter to switch. If a shutter that switches in about 3 ms to a state of perfect extinction is assumed, the leakage ratio for the right eye is similar to the numbers just given, but the leakage ratio for the left eye is increased to about 10% for a two section cell and to about 7% for a five section cell. Figure 4 shows the System Leakage for a 5 section cell.

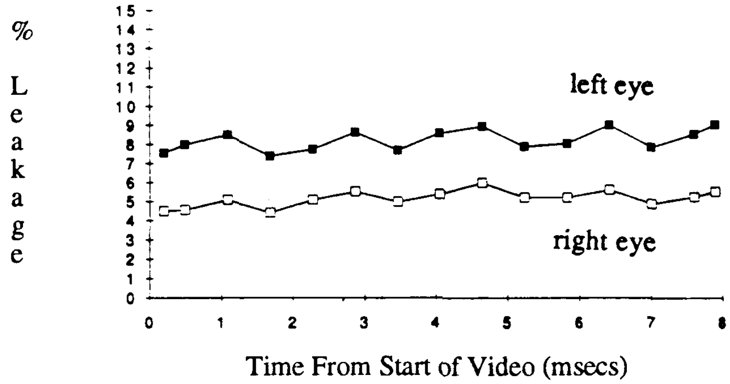

Figure 4: The SLR for a Five Section Shutter with a P-22 phosphor

The Improvement Resulting From the Use of a Rare-Earth Phosphor

As was pointed out previously, the persistence of the phosphor is a major contributor to the leakage of the incorrect image to each eye in field sequential stereoscopic displays. Systems using rare earth phosphors for the green color component, may be able to demonstrate a significant lowering of the system leakage ratio.

The problem with current phosphors is not so much related to what is frequently characterized as the decay time (the decay time to 10% peak intensity for a white image displayed using the P-22 phosphor set is about 350 micro-seconds) but rather is related to the low level image persistence that lasts for a considerably longer time. This characteristic is typical of Zinc Sulfide phosphors that are used for the blue and green colors in a standard P-22 color phosphor set.

Rare earth phosphors, on the other hand, have a different characteristic. In their case, while the time required for the light emission to decay to 10% of its peak value is actually greater than for a Zinc Sulfide phosphor, the long low level persistence is less significant. If P-43, a rare earth green phosphor, is substituted for the usual P-22 green phosphor in a color CRT, a significant difference in the phosphor decay characteristic of a white image can be observed. The following numbers give the amount of light that is emitted in successive milliseconds after a color CRT with P-43 used as the green phosphor is scanned (normalized so that the sum of the luminances is 100): 83; 12; 2; 1; 0; 1; 0; 0; 0; 0; 0; 0; 0; 0; 0; 1; 0; 0. The data shows that during the first 4 msecs 98% of the total light is emitted (as compared with only 91% for a white image displayed using the standard P-22 phosphor set).

System leakage data acquired from a color tube that used a rare earth green phosphor is shown in figure 5 For this data the same five section shutter was used as that was used to acquire the data for figure 4.

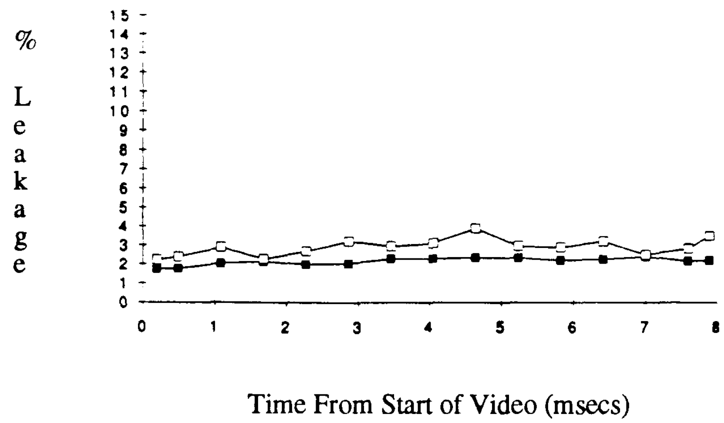

Figure 5: The SLR for a Five Section Shutter with a P-43 phosphor

Summary

It has been shown that a major contributor to the ghost image intensity , as quantified by the System Leakage Ratio, it due to the persistence of the CRT's phosphor. Two approaches to solving this problem were presented. One is to use a system that has a sectioned electro-optical device mounted directly in front of the CRT, and the other is to use phosphors that have less persistence.

References

[1] P. J. Bos and K.R. Koehler / Beran " The Pi-cell: A Fast Liquid Crystal Optical Switching Device" Mol. Cyst. Liq. Cryst. **113**, 329 (1984)

[2] D. H. Mash et el "Improvements in or Relating to Stereoscopic Applications" US Patent 4,967,268 (1986)